

Reducing Risk of Waterborne Illness in Public Water Systems: the Value of Information in Determining the Optimal Treatment Plan

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BACKGROUND

EPA faces considerable challenges in designing drinking water regulations due to key variables that differ among community water systems:

- Occurrence of waterborne disease
- Treatment option
- Treatment cost per capita

This work estimates and compares the total social costs of different treatment and monitoring options for addressing *Cryptosporidium* risk, including the option contained in the proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2). We use the information contained in LT2's economic analysis to model key variables. Results indicate that the LT2 option minimizes total social costs.

THE PROBLEM

A conventional water treatment system serving 100,000 people is considering its options for treatment of its surface water and water quality monitoring. If the authors were decision-makers, they might want to do whatever minimizes the community's total social cost:

$$\text{Total Social Cost (per year)} = \text{Cost of Illness}$$

$$+ \text{Cost of Improved Treatment}$$

$$+ \text{Cost of Obtaining New Data}$$

We are concerned about risk of infection and illness caused by *Cryptosporidium* oocysts that are not removed or inactivated during treatment. Able to withstand chlorine disinfection, these oocysts can infect persons who ingest the treated water.

Three Options:

- a) status quo, which is maintaining conventional treatment
- b) install UV disinfection to achieve additional two logs (factor of 100) risk reduction
- c) collect 24 monthly source water samples, assay using EPA Method 1623 (with less than 100% recovery), and improve treatment as required by the proposed Long-Term 2 Enhanced Surface Water Treatment Rule

THE RISK MODEL

Uncertain Parameters

1. *Crypto* in Source Water = C, oocysts per liter.

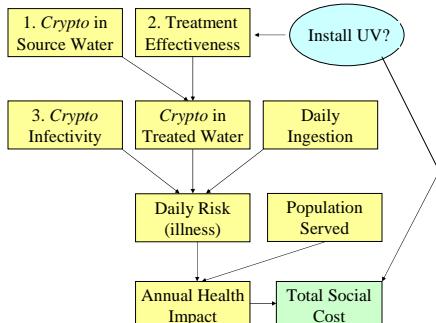
$[\ln(C) - 0.0477]/1.56 \sim t(6df)$.

Fraction capable of infecting humans = p $\sim U(0.15, 0.5)$

2. Treatment Effectiveness, as "log removal" $\sim U(2, 4)$.

3. Infectivity, as expected probability of infection, given exactly 1 oocyst ingested = r.
 $\ln(r/(1-r)) \sim N(-2.9, 1.25)$.

$P(\text{illness}|\text{infection}) = q \sim U(0.3, 0.7)$



Other Parameter Definitions

Population Served = 100,000

Cost of UV = \$2 per person-year

Daily Ingestion averages 1.2 Liters, 350 days per year

Value of each Illness Avoided = \$745

UV disinfection will disinfect 99% of oocysts not removed by conventional treatment.

Method 1623: Volume assayed = 10L. Cost per assay = \$530. Method recovery ~ Beta(2, 3).

Disclaimer: The findings and conclusions in this poster are those of the authors and do not necessarily represent the views of the Environmental Protection Agency..

COMPUTATIONS / MODELING

Expected annual risk under option a is as follows:

$$\int_{L_{\min}}^{L_{\max}} \int_{\ln(C)_{\min}}^{\ln(C)_{\max}} \int_{\mu_C - 7\sigma_C}^{\mu_C + 7\sigma_C} \int_{\mu_T - 7\sigma_T}^{\mu_T + 7\sigma_T} \frac{\left(\frac{-e^r}{1-e^{-\frac{1}{2}\sigma_U^2}} \right)^{\text{VOL DAYS INF} \cdot 10^{-L} \cdot e^{\ln(C)}}}{\sigma_U (\ln(C)_{\max} - \ln(C)_{\min}) (L_{\max} - L_{\min})} dr d\ln(C) dL d\ln(F) dL = 4.993 \times 10^{-3}$$

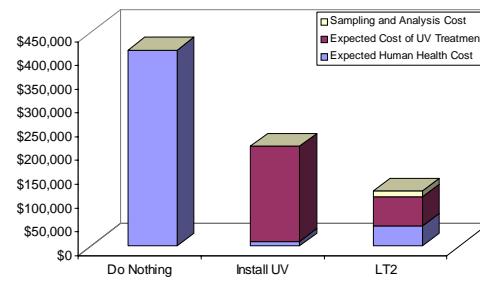
To estimate risk under option b, term L is replaced with L+2, the total log removal and UV disinfection.

The cost of doing nothing, given true source water concentration C is simpler. Again, the cost of installing UV involves replacing L with L+2:

$$\int_{L_{\min}}^{L_{\max}} \int_{\ln(C)_{\min}}^{\ln(C)_{\max}} \int_{\mu_C - 7\sigma_C}^{\mu_C + 7\sigma_C} \int_{\mu_T - 7\sigma_T}^{\mu_T + 7\sigma_T} \frac{\left(\frac{-e^r}{1-e^{-\frac{1}{2}\sigma_U^2}} \right)^{\text{VOL DAYS INF} \cdot 10^{-L-2} \cdot e^{\ln(C)}}}{\sigma_U (\ln(C)_{\max} - \ln(C)_{\min}) (L_{\max} - L_{\min})} dr d\ln(C) dL d\ln(F) dL$$

The math becomes more complex when imperfect monitoring data are modeled. There just isn't enough room here to do it justice, so we'll skip to the results.

RESULTS



The figure above shows that:

- * the option of installing treatment greatly reduces human health risk, compared to the status quo (maintain only conventional treatment)
- * the best of the three options is LT2, where new information on occurrence results in UV treatment only if occurrence is high, and only conventional treatment if occurrence is low.

EXTENSIONS

Some ideas for follow-on work:

- a) repeat the above, but for a much larger or much smaller system, to understand the importance of different per capita treatment costs
- b) collect 24 monthly samples, assay using EPA Method 1623, but improve treatment only if doing so minimizes total social cost (could result in a different "action level" than the 0.075 oocyst per liter level specified by LT2)
- c) collect some other number of monthly samples, assay with Method 1623, and then minimize total social cost (could identify the optimal number of samples to collect and assay)
- d) assess the value of obtaining perfect information (i.e., knowing the true, correct mathematical models and having exact model parameter values) for any of the following:

- *Cryptosporidium* occurrence in the source water
- *Cryptosporidium* dose-response
- The effectiveness of conventional treatment in removing *Cryptosporidium*

Item d, assessing the value of perfect information, could inform EPA's prioritization of research in these areas.

REFERENCE

Economic Analysis of the Long-Term 2 Enhanced Surface Water Treatment Rule, Proposed June, 2003. <http://www.epa.gov/safewater/LT2>



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